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# Mesh Shrinkage in Fishing Nets

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# Mesh Shrinkage in Fishing Nets


## E S Strange

### Marine Laboratory, Aberdeen


**Introduction**

The Nature of the Problem

Regulations prescribe minimum mesh sizes that may be used legally in fishing nets. Mesh sizes are determined in the light of our knowledge of particular fisheries and are applied to allow the small immature fish to escape from the net, and thereby conserve the stocks. If the meshes in the codend are undersized, fish stocks could be at risk, and if the meshes there are much larger than the legal requirement, then the net will catch less fish. Thus it is important that the mesh size of codends is at or not much above the permitted minimum size and that the meshes stay that size.

The mesh size is determined by the length of the twines which form the mesh. Unfortunately, the length of twines from which fishing nets are made may change for several reasons. The twine may shrink when heated or soaked in water. Retention of sand in some twines increases twine diameter which is compensated by a reduction of twine length. Prolonged exposure to sunlight may cause the twine to shrink. Twines are elastic and when they are loaded they stretch and length is increased. Sometimes this increase is not reversible.

The Marine Laboratory in Aberdeen has investigated mesh shrinkage by making a series of measurements on nets and twines which have undergone various treatments. It is not practical to measure the mesh size without stretching the twines to some extent, so we have looked also into the effect of twine loading on the indicated mesh size.

Scope of the Investigation

Today the most commonly used materials for making fishing nets are polyamide (nylon), polyethylene (eg Courlene) and to a lesser extent polypropylene (eg Ulstron). The Marine Laboratory tested a selection of twines and netting made of these materials to determine their reaction to known and suspected causes of shrinkage, viz. immersion in water, heating, the ingress of sand and long term storage. The information obtained during the investigation and presented in this pamphlet is intended to aid fishermen and enforcement agencies by describing the shrinkage observed in various materials under commonly encountered circumstances. Our investigations were not by any means exhaustive. Only a small selection from a wide range of twines and netting available to fishermen was tested. The results illustrate the magnitude of shrinkage which can occur but, due to the variability of the materials, they cannot be used to guarantee the mesh size in a net design which will allow for possible shrinkage. Our investigations do show that users of nets need to be constantly on the alert for mesh shrinkage.

The Measurement of Mesh Size

For the purpose of this report, mesh size is defined as the inside distance between opposite knots in the same mesh when fully extended diagonally lengthwise of the net. The usual method of measuring this is to stretch the mesh in the appropriate direction and push into it a flat gauge, 2 mm thick and of graduated width (see Plate I) until it no longer passes easily

through, as judged by the measurer. Thus the twine of the mesh is tensioned by an uncertain amount during measurement of mesh size. Variation of measured mesh size between individuals applying different amounts of force with the gauge on the same mesh may be significant.

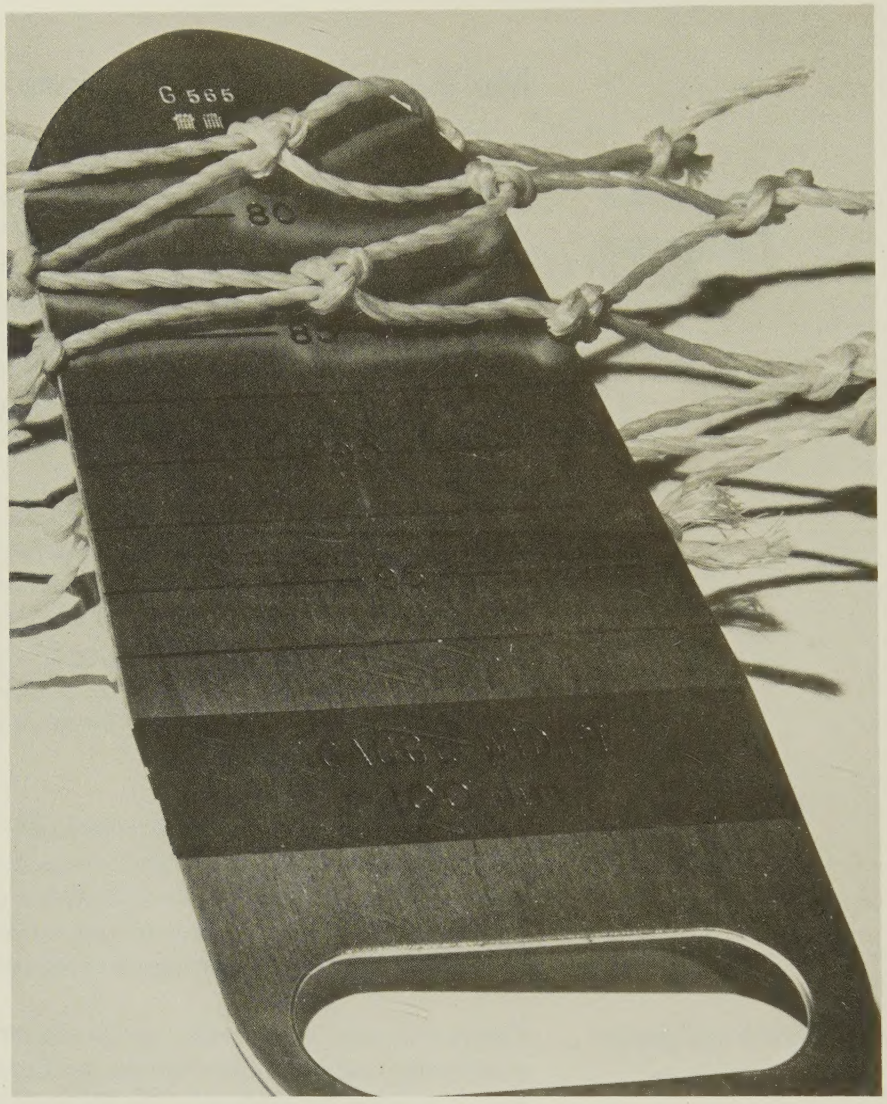


**Plate I. Wedge-shaped mesh gauge**

A more precise method of measuring mesh size is used for many scientific purposes. The instrument used is illustrated in Plate II and is known as the ICES gauge. It is designed to apply a prescribed stretching tension to the mesh, normally 4.0 kg. The twine each side of the stretched mesh is tensioned 2.0 kg if it is made of single twine, and 1.0 kg if it is made of double twine, at which tension the gauge locks and the indicated mesh size is read. Thus, the same tension is applied each time the gauge is used irrespective of the user. The ICES gauge is the better type for the kind of mesh measurements described in this pamphlet, although it is not used for enforcement purposes owing to legal requirements in certifying the gauge calibration.

Both these mesh measuring methods involve applying tension to the mesh so that the twine of the mesh stretches. The twine elongation is a component of the measured mesh size. Clearly any methodical assessment of mesh shrinkage based on comparison of mesh measurements must take account of the elongation during measurements. The amount by which the twine elongates depends on the amount of applied tension, the elastic quality of the twine and the twine thickness.

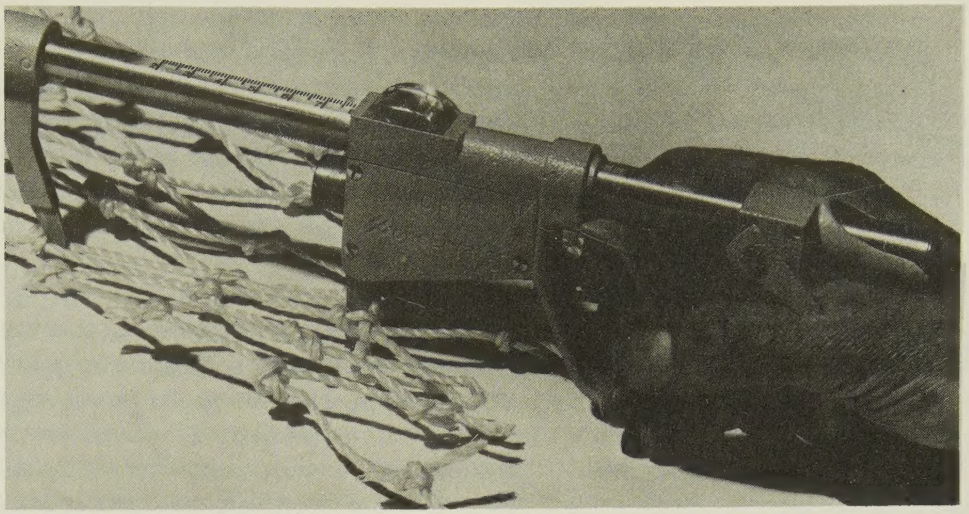

**Plate II. ICES spring loaded mesh gauge (ICES = International Council for the Exploration of the Sea)**

Twine R Tex

The thickness of twines used for making fishing nets is indicated by their R tex number. Tex is the mass in grams of one kilometre of plain yarn, and R tex is the resultant mass in grams when a number of yarns are twisted or braided into one kilometre of twine. The larger the R tex number, the thicker the twine, eg twisted nylon twines of R tex 920 and 3680 are approximately 1.2 mm and 2.3 mm thick; the thinner twine might be used in a small mesh codend for sandeels or shrimps and the thicker one in the codend of a medium sized white fish trawl. Braided twines appear more bulky than twisted twines of the same R tex value.

Twine Elasticity

The elastic qualities of twine vary not only with the properties of the materials from which they are made and their construction, eg twisted or braided, but also according to how much the fibres were stretched during the extrusion stage in manufacture.

Cook (1968) described how the long molecules in textile fibres are grouped into crystalline and amorphous regions. In the crystalline regions the molecules are orientated in the longitudinal direction of the fibre and here the forces of attraction holding the molecules together are very strong. In the amorphous regions the molecules are in random arrangement and they are not held tightly together. The crystalline regions provide strength and rigidity and the amorphous regions provide flexibility and reactivity according to the ratio of crystalline to amorphous material. At the extrusion stages in the manufacture of synthetic fibres, the fibres are stretched to draw more and more of the long fibres into crystalline regions. At this stage the manufacturer has some control over the ratio of crystalline to amorphous material to obtain the best compromise between the strength and reactivity qualities of the fibres appropriate to the requirements of the products to be made from them, eg cloth for the clothing industry, or ropes, twines and nets for the fishing industry.

Fibres for twines destined for the fishing industry pass through a number of twisting or braiding operations. Twisting and braiding tends to enhance elasticity, twisting more so than braiding. The tighter the twist the more the twine can elongate to absorb stress. From the range of twisted and braided products available for making nets it is possible to choose twines with regard to the type of net to be made, eg twines of tight twist for a herring midwater trawl for which high absorption of stress is required. The different types of twines, their construction and properties are described in detail by Klust (1982).

Treatment of Netting

Many manufacturers treat their netting to adjust and/or stabilise mesh size and the knots. Treatments vary to suit the material of the netting and between manufacturers. Treatments may involve soaking in cold or hot water, boiling, dry heating and stretching of the netting. A more complex treatment of nylon netting involves stretching large sections on a frame and sealing this in an autoclave where it is exposed to superheated steam. At the end of the treatment the frame is withdrawn and the netting is allowed to cool and dry before removal. It is known that most synthetic fibres will shrink in the presence of heat and that nylon shrinks in water. Depending on the manufacturer's treatment of his netting, the material may try to shrink during the process and depending on how tightly the netting is stretched to oppose shrinkage, the ratio of crystalline to amorphous material will be modified. Thus the shrinkage and elasticity qualities of netting can vary between manufacturers. One treatment recently developed involves impregnating the material of the netting with a waterproof resin after the netting is made.

It is generally believed that in normal atmospheric conditions shrinkage in most synthetic fibres is imperceptible. In the long term, however, shrinkage may be significant. One manufacturer reported that following a complaint that shrinkage had occurred in some nylon netting purchased from them, an investigation revealed that the netting had been stored under a roof window where it was exposed to sunlight and had shrunk.

**Elongation and Water Shrinkage Tests**

General Procedures

Twisted and braided nylon, polypropylene and polyethylene twines were obtained from a number of suppliers. Five samples of each type and size were tested for elongation and their reaction to immersion in sea-water. All wet and dry measurements were made using a simply constructed measuring board as shown in Figure 1. Each sample was given a loop at each end for attachment to the measuring board and weight, and two knots to mark the portion to be measured. The typical knot spacing was 90 cm. Each sample wa progressively tensioned on the measuring board with lead rings of known weight. The distance between knots was measured immediately after a weight was hung on the sample. Thus data on elongation and shrinkage were obtained at the same time. All measurements were made to an accuracy of approximately 0.1%.

After the samples were measured they were immersed for up to several days in a covered dark tank filled with sea-water positioned outside away from direct sunlight. Periodically the samples were removed from the tank and measured whilst still wet. Then they were returned to the tank either immediately or after they had been dried naturally and measured again. Finally all samples were measured dry.

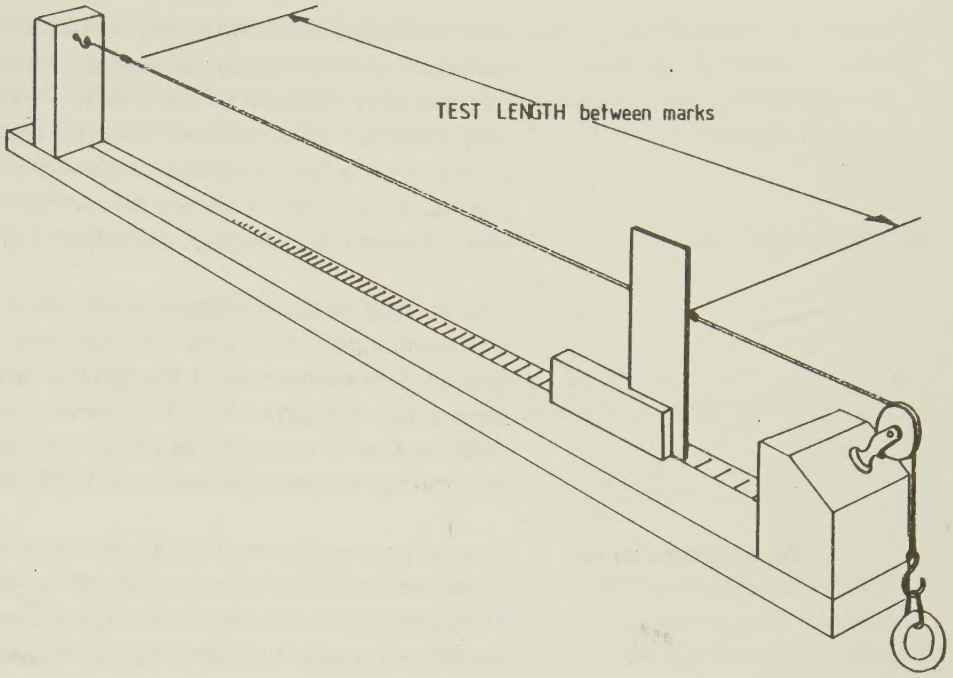


**Figure 1. Twine length measuring board**

Test Results

*Elongation*

**Nylon Twines**

Figure 2 shows percentage elongation of nylon twines when samples of these were progressively tensioned on the measuring board during the tests. Continuous and broken lines represent wet and dry state of the twines, respectively, as they do in all the graphs presented in this pamphlet. Whilst all samples shrank (see Fig. 6) such that their unstretched length was a

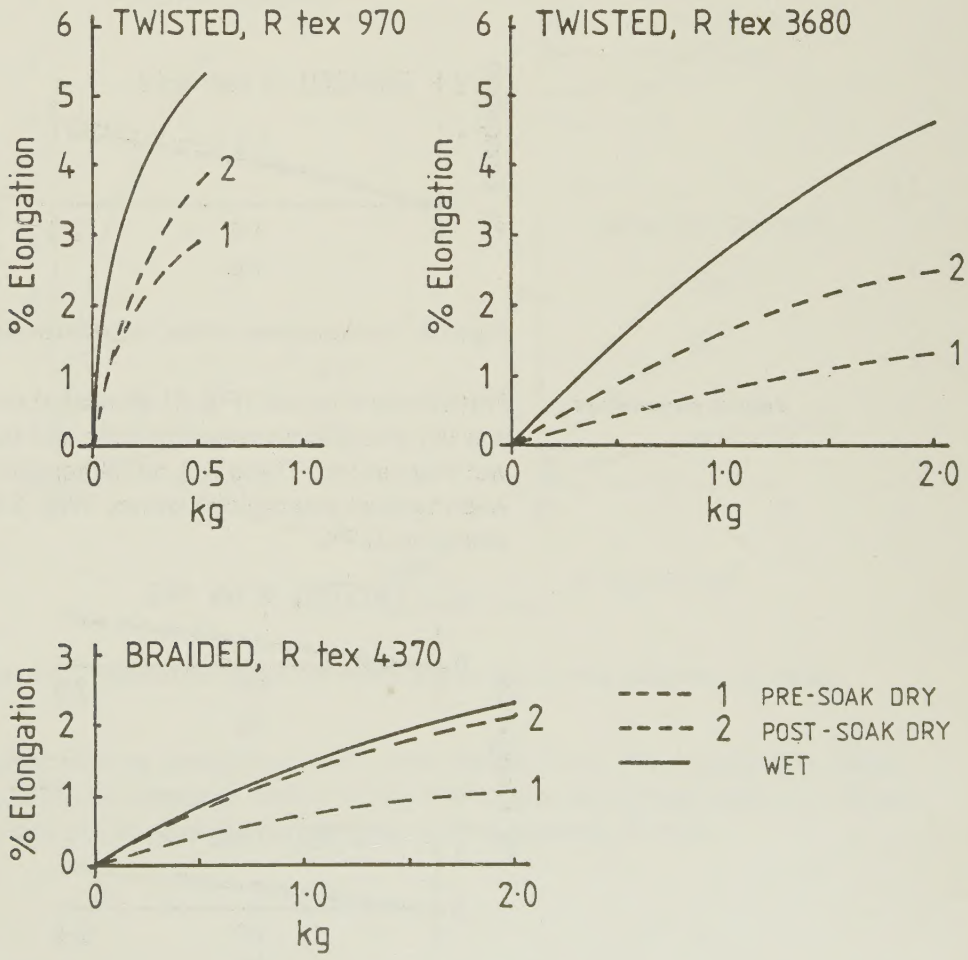


**Figure 2. Nylon twines: elongation with applied tension**

little different each time they were measured, percentage wet elongation varied very little between sequences of wet measurements and it is the average of these that is shown in the graphs. Percentage dry elongations also varied very little once the twines had been soaked, but these were noticeably greater than initial elongation before the twines were first immersed. In the graphs, broken line 1 shows percentage initial dry elongation and broken line 2 shows the average of subsequent dry elongation percentages.

The twisted twines elongated more when wet than when dry but wet and dry elongations of braided samples were about the same once these had been soaked. Dry elongation of the thicker twisted twine and the braided twine were about the same (in 2.0 kg tension, about 1% pre-soak and 2% post-soak) but, when wet, the same twisted twines elongated 4.6% compared with the braided twines' elongation of 2.2% (see also Fig. 5).

**Polypropylene twines**

Polypropylene twines (Fig. 3) were much less extensible than nylon twines. There was hardly any perceptible difference between pre-wet and post-wet dry elongations and both were slightly greater than wet elongation. In 0.5 kg tension elongation of the thinner twisted twine was 0.5% compared with 5.2% wet elongation of the thinner twisted nylon twine at the same tension.

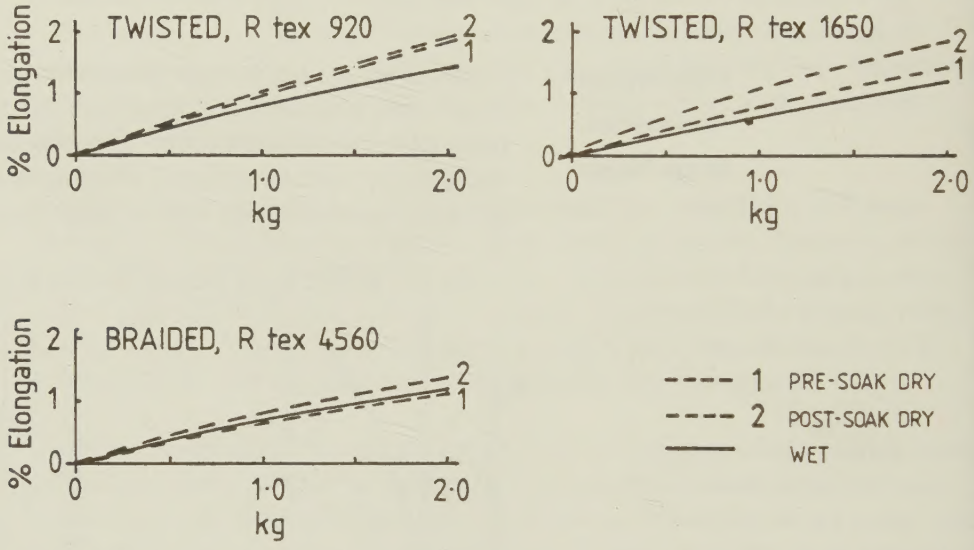


**Figure 3. Polypropylene twines: elongation with applied tension**

**Polyethylene twines**

Polyethylene twines (Fig. 4) elongated only very little. Pre-wet and post-wet dry elongations were the same and these were hardly different from wet elongations. There was no perceptible difference in elongation between twisted and braided twines. With 2.0 kg tension the thinnest twines elongated 0.7%.

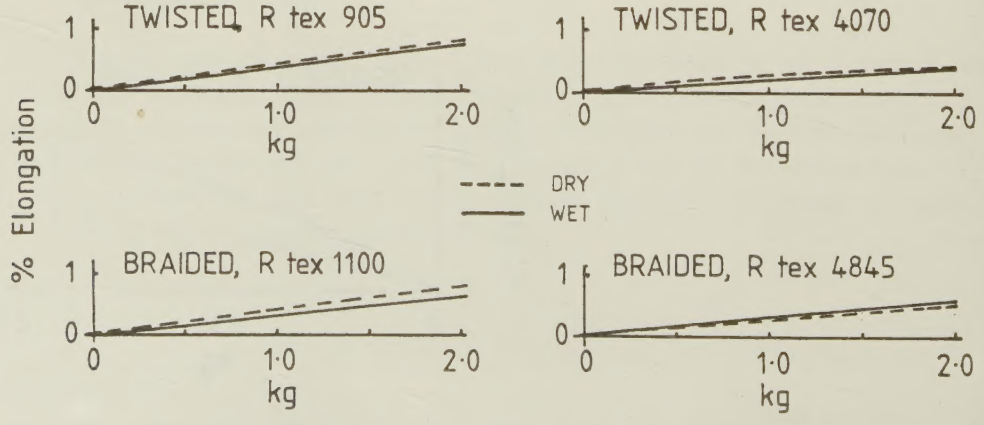


**Figure 4. Polyethylene twines: elongation with applied tension**

*Twine stress/strain curves*

Stress/strain curves were plotted for all the twine samples tested, ie measured elongation was plotted against applied tension divided by the cross-sectional area of the material from which the twine was made. Cross-sectional areas were derived from R tex values and the density (d) of the material in $kg/m^3$, as follows:—

$$\text{R tex} = \text{mass of 1 km of the twine in grams}$$

$$\text{mean cross-sectional area} = \frac{(\text{R tex})\ 10^{-6}}{d} \quad m^2$$

$$\text{Stress} = \frac{\text{Load}}{\text{Cross-sectional area}}$$

$$= \frac{\text{Load} \times d \times 10^6}{\text{R tex}} \quad kg/m^2$$

The curves showed quite wide variance between different sizes of twines made of the same material. This probably is due to different twine construction, ie braided, twisted, degree of twist, different sizes of strands and number of filaments. Together these could modify the frictional forces between filaments and between strands and affect the extensibility of the twines. Figure 5 shows "best average" curves for all twisted and braided twines of the same materials. In these graphs the broken lines represent dry elongation after the samples had been immersed for at least a day and then dried. The graphs show clearly the difference in elongation qualities of twines made of the different materials, the most significant being that nylon twines elongate much more than twines made of polypropylene or polyethylene.

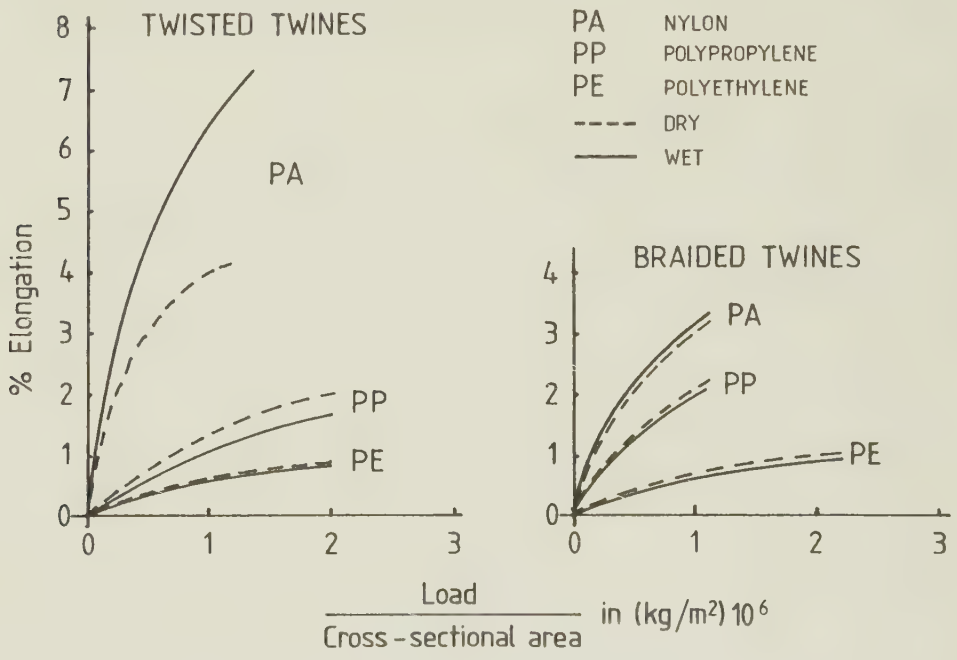


**Figure 5. Stress/strain curves for nylon, polypropylene and polyethylene twines**

Table I shows theoretical mesh sizes derived from the stress/strain curves as might be measured with a 4.0 kg mesh gauge on meshes made of different twines and all of which under zero tension measure 80 mm.

Table 1

**Predicted Sizes of some '80 mm" Meshes, made of Different Twines, when the Meshes are stretched by a 4.0 kg Gauge (based on Fig. 7)**

| R tex | | 4,000 | | | | 2,000 | | | |
|---|---|---|---|---|---|---|---|---|---|
| Single/Double Twine | | Single | | Double | | Single | | Double | |
| Dry/Wet | | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet |
| | | mm | mm | mm | mm | mm | mm | mm | mm |
| Nylon | Twisted | 82 | 84 | 81 | 83 | 83 | 86 | 82 | 84 |
| | Braided | 82 | 82 | 81 | 81 | 83 | 83 | 82 | 82 |
| Polypropylene | Twisted | 81 | 80 | 80 | 80 | 81 | 81 | 81 | 80 |
| | Braided | 81 | 81 | 81 | 81 | 81 | 82 | 81 | 81 |
| Polyethylene | Twisted | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |
| | Braided | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |

*Shrinkage*

In tests in cold water, nylon twines shrank whilst twines made of polypropylene or polyethylene did not. Figure 6 shows the amount of shrinkage that was calculated to have occurred during the tests in twisted and braided nylon twines from two suppliers. The calculations are based on twine lengths at zero tension that were derived by extrapolation from graphs of twine lengths measured under different applied tensions on the measuring board, ie from the same length/tension data used for percentage elongation curves.

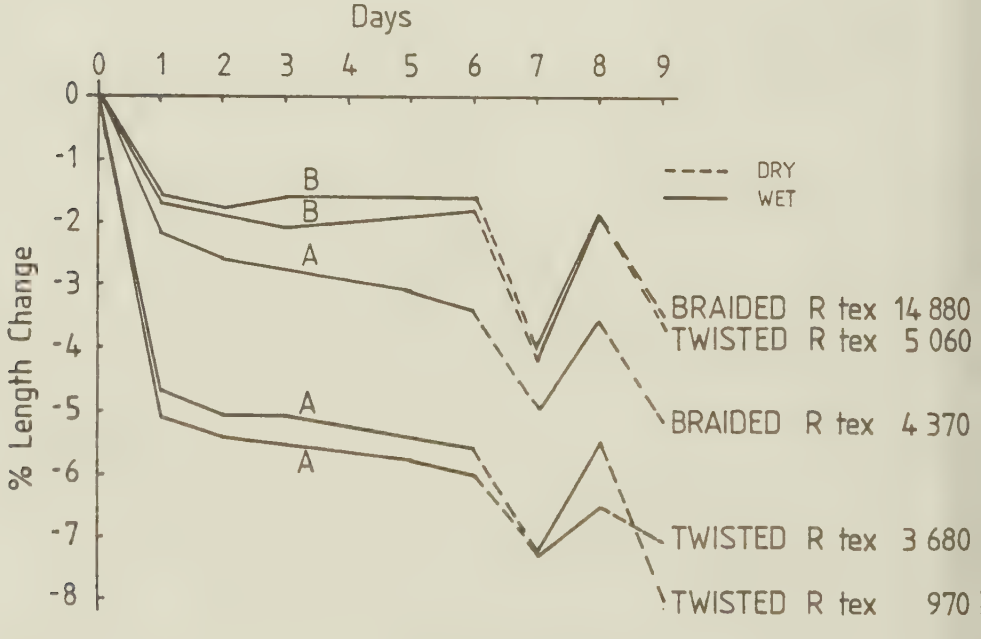


**Figure 6. Shrinkage of nylon twines from suppliers A and B, as measured under zero tension**

The twines from one supplier (A) shrank more than those from another supplier (B). This may be due to some variation in processing control between manufacturers or a difference between the ages of the samples. The age of the samples is not known but sample B may have had the longer shelf life and knowing that some shrinkage occurs in nylon during storage, this may account for the difference in the test results. Shrinkage during storage is discussed later (see page 13).

In general twisted twines shrank more than braided twines. The reason for this may be due mainly to the braid angle being greater than the average orientation of the twisted fibres to the longitudinal axis of the twine, for if the fibres shrink mainly in the direction of their longitudinal axis, then the resultant change of twine length will equal fibre shrinkage cos $\theta$, where $\theta$ = angle of fibre orientation.

All the twines shrank quite quickly during the first 24 hours of soaking: twisted and braided twines from supplier A shrank by 4.5 - 5.0% and 2.3% respectively; twisted and braided twines from supplier B shrank 1.8%. Thereafter, the twines shrank more slowly until they were removed from the tank after soaking for 6 days. As they dried they shrank a further 1.5-2.5%. When the twines were re-immersed, shrinkage relaxed and when they were dried again, dry shrinkage recurred. It was found experimentally that shrinkage started to relax immediately the twines were re-immersed and relaxation ceased within 10 minutes. When the results of days 6 and 8 in the graphs are compared, it appears that shrinkage which occurred during drying relaxed until relaxation was overcome by water shrinkage, and water shrinkage then continued at the same rate as before the twines were dried. The reason for the reversible length change with change of wet/dry state has not been identified. Both Cook (1968) and Klust (1982) refer to this but neither of them offers a reason for it.

Figure 7 shows how the amount of shrinkage that occurred in twisted nylon R tex 3680 was modified as the twines elongated with increased applied tension each time they were measured. Against each graph the applied tension under which twine length was measured is shown. The percentage length changes plotted in that graph were derived from these measurements. In the upper graphs (marked a) the percentage length changes are plotted with respect to the twine's initial dry length at zero twine tension. In the lower graphs (marked b) the percentage length changes in each graph are plotted with respect to the initial dry length of the twine as measured under the applied tension shown against the graph; thus the lower graphs are representative of results obtained independently using measuring instruments each with a tension rating different from the others.

The graphs show clearly how deceptive assessment of shrinkage in nylon twine can be if no account is taken of the wet or dry state of the twine, measuring tension and elongation when first and subsequently measured. However, the meshes in codends, normally the smallest meshes in a trawl or seine net, are usually made of double twine (unless they are small mesh codends, eg for sandeels, shrimps); the tension applied to stretch the meshes when they are measured is shared by four twine components. On the basis of the results shown in the upper graphs (Fig. 7a), dry measurements on double twine meshes in new codends made of twines similar to those tested using different tensions up to 4.0 kg to stretch the meshes, will agree with the unstretched mesh length within +0.8%.

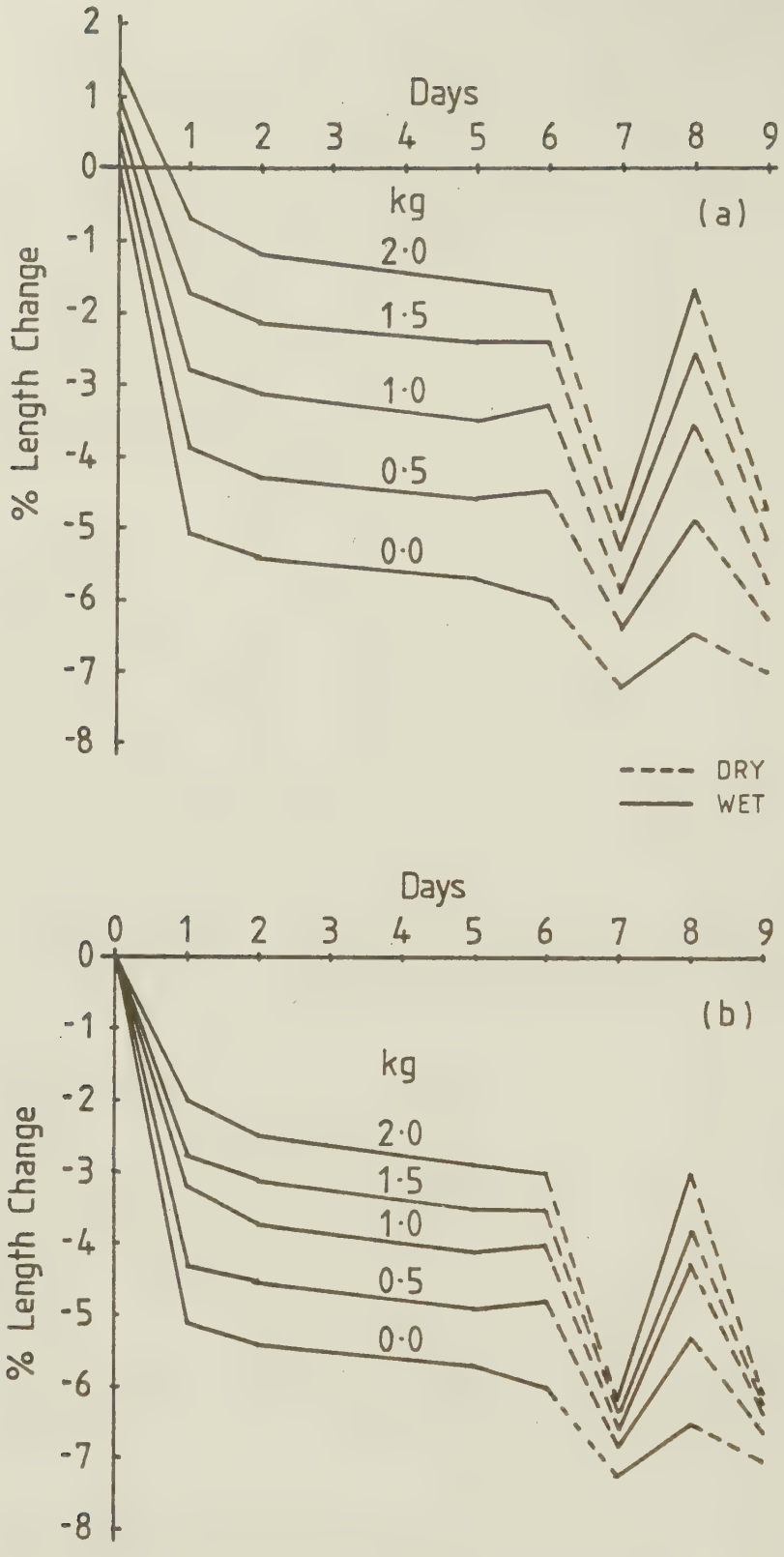


**Figure 7. How applied tension modified measured shrinkage of twisted nylon R tex 3,680**

According to the lower graphs (Fig. 7b), if the same meshes are measured dry sometime after the net has been used, calculations of mesh shrinkage with respect to initial length under whichever tension up to 4.0 kg was applied will agree within 0.8%; if the meshes are measured wet, calculations of shrinkage could differ by up to 2.0% due to the wet extensibility of nylon being greater than its dry extensibility. Furthermore, because of the length change that occurs between wet and dry states of the twine, shrinkage as calculated from dry measurements could be up to 3% greater than if the meshes were measured whilst they were still wet. This strongly suggests that mesh sizes should be measured while the net is wet, if the intention is to check the mesh size in the fishing condition.

**Sand Shrinkage**

Mesh shrinkage at sea sometimes has been attributed to sand seen inside the braid of the twine. To investigate this the White Fish Authority (now the Sea Fish Industry Authority) and the Marine Laboratory co-operated in sea trials using a selection of codends on sandy grounds. The only evidence of sand shrinkage was seen in the lower side of a braided nylon codend when a large boulder was caught. The mesh size here was 4% smaller than in the upper side. Examination of the meshes after the next haul showed that the sand had been flushed out and the mesh size in the lower meshes was restored to that of the upper meshes.

Tests were conducted by Messrs Cosalt Ltd, Grimsby, with the assistance of the writer, on a sample cut from a sheet of netting made of double braided nylon twine that had been steam-treated in the company's autoclave for 20 minutes. The sample was soaked for 10 minutes in which time mesh size increased 1.8%. Whilst still wet, the sample was then sealed in a drum containing clean water and tumbled for 15 hours. During this time the meshes shrunk 0.9%. When the sample was dried the meshes shrank another 1.9%, a reversal of the first length change. The sample was then tumbled in a mixture of sand and water for 2½ hours. By then a substantial quantity of sand was trapped inside the twine and wet mesh size had shrunk another 5.5%. The results are shown plotted in Figure 8 with respect to the first dry measurements.

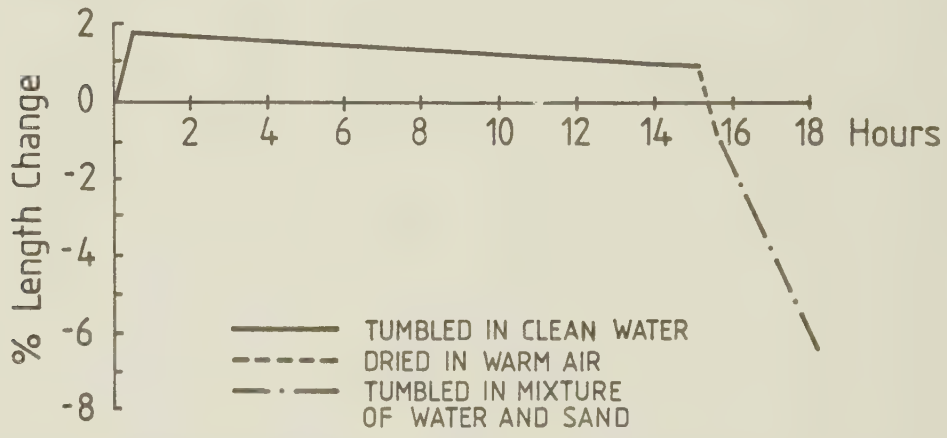


**Figure 8. Mesh shrinkage of braided nylon netting when tumbled in a mixture of sand and water**

The meshes were put into the mixture of water and sand whilst they were still dry. Therefore, allowing +1.9% mesh length change from their dry to wet state, the amount of shrinkage attributable to ingress of sand was probably about 7.5%. If this amount of sand shrinkage occurred in a codend made of untreated braided nylon netting, and fished for two or three weeks, combined sand and water shrinkage could be 10-15% or more.

Another piece of nylon netting that had been tumbled in a mixture of sand and water for several hours was examined. The twine had been considerably fluffed, presumably by the sand, and it was clear that this too had reduced mesh size. Photographs of fluffed netting are given by Klust (1982).

**Heat Shrinkage**

It might be supposed that heat shrinkage ought not to be a problem for nets used at sea. However, nets may come into contact with engine exhaust outlets, hot pipes or escaping steam or hot water. Samples of nylon, polypropylene and polyethylene twines boiled for five minutes were found to have shrunk by 14%, 10% and 12% respectively.

Figure 9 shows the amount of shrinkage that occurred in samples of polyethylene twines when these were exposed to dry heat in an oven pre-heated to different temperatures. The samples, from four suppliers, were of a size typical for making codends. Fresh samples were used for each heat test. All measurements were made with the twines in 0.2 kg tension. The results indicate that shrinkage may have started between 40 and 50°C. Samples exposed to 70°C of heat for five minutes shrank 2-4% and those exposed to 80°C of heat for five minutes shrank 7.5-9.5%. Dry heat tests on twines made of other materials have not been conducted, but mesh size may be at risk if nets made of nylon, polypropylene or polyethylene twine are placed against a hot surface or are inadvertently subjected to hot water.

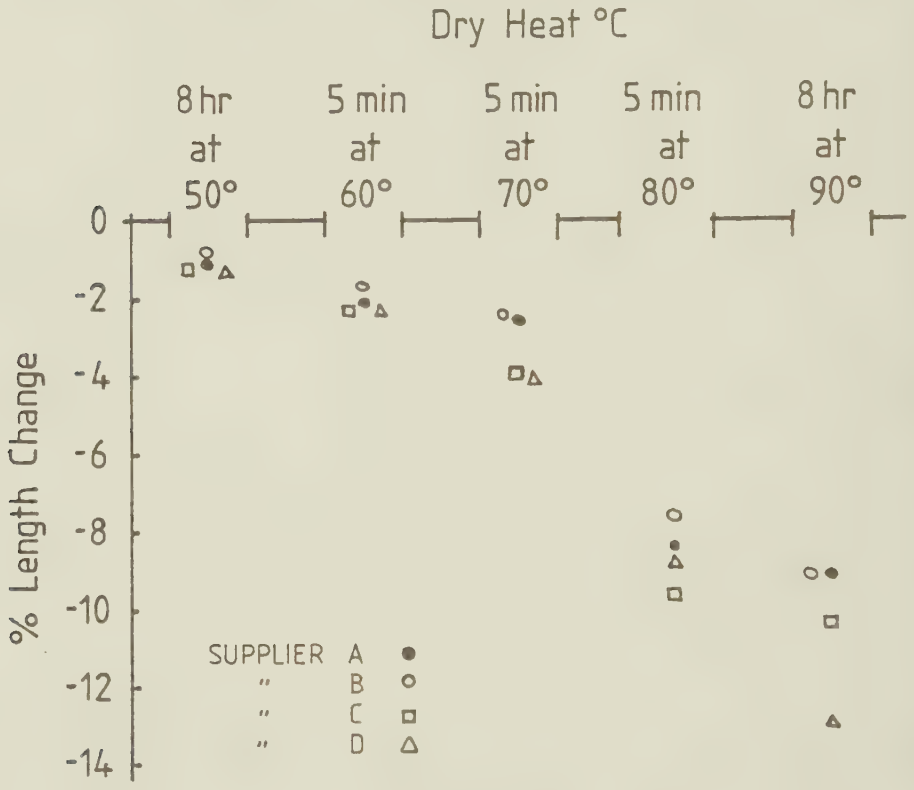


**Figure 9. Shrinkage of twisted polyethylene twines R tex 1,600 in dry heat. Samples from suppliers A, B, C and D**

**Shrinkage in Stored Nets**

On many small boats spare nets are often kept uncovered on deck in open-sided pens behind the wheel-house where they are exposed to daylight. There is evidence that polyethylene nets when so exposed for a long time may shrink. Pieces of machine made polyethylene netting from three manufacturers (identified A, B and C) were kept uncovered on top of a flat roof for six months (May to October). At the same time other samples of netting from the same consignments were kept in a cool windowless brick building. All the netting conformed to the manufacturers' normal commercial standards for codends on prawn trawls. All manufacturers had treated their netting differently, viz. netting A was cold stretched to tighten the knots, netting B was steam set under tension, whilst netting C was set under tension in dry air heated 90-115°C. Despite these treatments none of the knots in any of the samples seemed particularly tight.

Each week throughout the six month test period the same three blocks of 30 meshes in each manufacturer's netting were measured with a 4.0 kg mesh gauge. Graphs of the average weekly percentage mesh length change with respect to their initial measured length are shown in Figure 10. Mesh size in all those kept in darkness progressively increased. Possibly under the influence of repeated tensioning with the mesh gauge, the knots gradually tightened and thereby mesh bar length was increased. By the end of the

test period mesh size in netting A, B and C had increased 8%, 2% and 3% respectively. Of the netting kept in the open, mesh size in netting C changed very little and in netting B it increased 1.5%. Netting A shrank, with mesh size changing quite irregularly; by July the meshes had shrunk 5% and thereafter their size fluctuated between 95% and 97% of their original length. If the increase in mesh size in netting kept in darkness resulted from repeated tensioning during measurement, the same influence applied to netting kept in the open. Therefore, the difference in length change in Figure 10 between dark storage and open storage for each sample suggests that during open storage netting B, C and A shrank by about 1%, 3% and 13%, respectively.

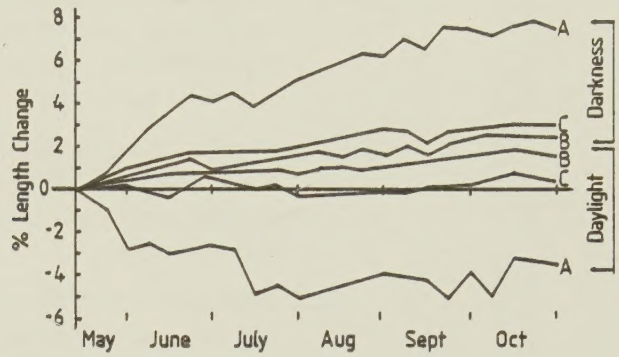


**Figure 10. Mesh length change in netting made of twisted polyethylene from suppliers A, B and C, when stored in dark and daylight**

During a four week summer research cruise in the period when the storage tests were undertaken, a standard polyethylene prawn trawl with a new codend was used intermittently for a total of 22 hours. When the trawl was not being used it was left uncovered alongside on deck. The opportunity was taken to obtain some codend mesh measurements at sea to compare with the results of the storage tests. Before the net was first used, 30 meshes in the upper side of the codend were measured with a 4.0 kg mesh gauge. The same meshes were measured three times during the cruise and at the end of the cruise. By the end of the cruise these meshes had shrunk 8.5% of their original length in four weeks. Since the laboratory tests show that polyethylene twines do not shrink in water, shrinkage in the codend must have occurred whilst it was on deck, for most of which time it was daylight.

The cause of shrinkage in the netting kept in the open at the Laboratory and in the netting of the codend has not been identified. However, it is known that prolonged exposure to sunlight can cause degradation in some synthetic materials and it may be that sufficient solar energy, eg ultra-violet, penetrated the netting and caused it to shrink.

Do nets made of other materials shrink when they are stored? Shrinkage in store of polypropylene nets has not been reported but mention was made earlier of shrinkage having occurred in nylon netting stored under a roof window. Some of the samples of twisted nylon twines used in the above elongation and shrinkage tests were taken from a spool from which six months earlier a small piece of netting was made. This was tested for shrinkage soon after it was made. The shrinkage that occurred was a few percent more, as measured with a 4.0 kg measuring gauge, than had occurred in samples from the same spool six months later. It is tentatively concluded that some shrinkage may have occurred on the spool during the time between tests when it was kept in a cupboard at normal room temperature. If this occurred at a uniform rate, shrinkage would have been imperceptible in the short term.

## Conclusions

The following conclusions are drawn from these investigations on the stability of mesh size in nets made of nylon, polyethylene and polypropylene:

### General

1. Shrinkage and elongation qualities of netting used for fishing nets can vary significantly between manufacturers.
2. Mesh size can decrease in the presence of heat, eg when nets are placed against exhaust outlets, hot pipes, or when exposed to steam or hot water.

### Nylon nets

1. Wet mesh size is greater than dry mesh size.
2. In codends made of heavy double twine, variation of mesh size with variation of applied tension up to 4.0 kg will be small, but in netting made of light single twine such variation could be critical, the more so when the net is wet.
3. In nets made of untreated twine not stabilised in any way after it is made, mesh size will decrease significantly during the first 24 hours of normal fishing use and will continue to decrease for several days and perhaps longer.
4. Mesh size in nets that have been stabilised, or shrunken during previous use, will increase a percent or two when the nets are first re-immersed; thereafter further shrinkage may occur.
5. In time, some dry shrinkage may occur in untreated nets stored before they are first used.

### Polyethylene

1. In codends made of polyethylene the difference between wet and dry mesh measurements is insignificant and variation in mesh size with variation of applied tension up to 4.0 kg is insignificant for practical purposes.
2. Polyethylene nets do not shrink in cold water, but significant shrinkage may occur during prolonged exposure to sunlight.

### Polypropylene

1. In codends made of polypropylene the difference between wet and dry measurements is hardly significant and variation of mesh size with variation of applied tension up to 4.0 kg is less than 2%.
2. Polypropylene does not shrink in cold water.

### Sand shrinkage

Under some circumstances, which may be fortuitous, sand may penetrate braided yarns of codends and cause mesh length to shorten several percent. In braided nylon codends combined sand and water shrinkage may be 10-15% or more.


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